Protocol-driven vs. physician-driven electrolyte replacement in adult critically ill patients

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BACKGROUND: The intensive care unit is a dynamic environment, where high numbers of patients cared for by health care workers of different experiences and backgrounds might result in great variability in patient care. Protocol-driven interventions may facilitate timely and uniform care of common problems, like electrolyte disturbances. We prospectively compared protocol-driven (PRD) vs. physician-driven (PHD) electrolyte replacement in adult critically ill patients.

PATIENTS AND METHODS: In the first month of the two-month study, potassium, magnesium, and phosphate levels were checked by a physician before ordering replacement (PHD replacement period). Over the second month, ICU nurses proceeded with replacement according to the protocol (PRD replacement period). We collected demographic data, admission diagnosis, number of potassium, magnesium, and phosphate levels done per day, number of low levels per day, number of replacements per day, time between availability of results to ordering replacement, time to starting replacement, post-replacement levels, serum creatinine, replacement dose, arrhythmias and replacement route.

RESULTS: During the PHD replacement period, 43 patients meeting the inclusion criteria were admitted to the ICU, while 44 were admitted during the PRD month. The mean time (minutes) from identifying results to replacement of potassium, phosphate and magnesium was significantly longer with PHD replacement compared with PRD replacement (161, 187, and 189 minutes vs. 19, 26, and 19 minutes) ($P<0.0001$). The number of replacements needed and not given was also significantly lower in the PRD replacement period compared with the PHD replacement period (2, 4, and 0 compared with 9, 6 and 0) ($P<0.05$). No patients had high post-replacement serum concentrations of potassium, phosphate or magnesium.

CONCLUSIONS: This study shows that a protocol-driven replacement strategy for potassium, magnesium and phosphate is more efficient and as safe as a physician-driven replacement strategy.

Protocol-driven health care interventions, which reduce morbidity and mortality,[1] are increasingly used to direct the care of common problems in critically ill patients.[2] Studies have shown that protocol-directed weaning and sedation were more effective than the usual physician-directed interventions.[3-5] An analysis of the practices of 108 intensive care units (ICUs) revealed that using protocol-directed interventions was associated with better patient survival and highly efficient resource use.[6] Units with the shortest ICU and hospital stay had used multiple protocols for their care processes. The dynamic nature of the ICU environment, with high turnover of health care workers, calls for management guidelines and protocols to ensure effective, uniform, and timely care.[7]

Electrolytes are routinely monitored in critically ill patients as disturbances are common,[2,8-11] and can lead to deleterious outcomes.[12] The development of hypomagnesaemia during an ICU stay is associated with a worse prognosis and a higher mortality rate.[13] Aubier et al found that hypophosphatemia leads to difficulties in weaning from the ventilator by impairing the contraction of the diaphragm in critically ill patients.[14] Hypophosphatemia is also associated with respiratory infection and decreased cardiac output after myocardial infarction.[15,16] Hypokalemia, on the other hand, increases the

arrhythmogenicity of the heart and can lead to muscle necrosis. It can eventually impair respiratory function and lead to respiratory failure.[17] In most ICUs, such disturbances are usually detected and corrected by physicians (physician-driven replacement). The busy ICU environment and the fact that residents from different backgrounds rotate through the ICU may result in inconsistencies and delays in attending to common problems that are encountered on a daily basis, such as electrolyte disturbances.

The objective of this study was to compare the efficiency of a protocol-driven replacement (PRD) with a physician-driven replacement (PHD) strategy for the correction of hypokalemia, hypomagnesemia and hypophosphatemia in critically ill patients. The hypothesis was that a PRD strategy results in a more timely replacement and misses fewer electrolyte disturbances than a PHD strategy in the ICU setting.

Patients and Methods

The study was conducted prospectively (before and after implementation of the PRD strategy) in a medical-surgical ICU with 14 beds in a 600-bed tertiary care center. All patients (≥14 years old) admitted to the ICU were included. In the month of the PRD strategy, patients with a serum creatinine ≥115 μmol/L, low urine output, dysrhythmias, diabetic ketoacidosis, seizures, weight <45 kg, and hypocalcemia were excluded.

During 2001, data were collected over one month of usual care (physician-driven replacement). Data collection was done daily without the knowledge of the ICU health care team. Collected data included demographics, diagnosis, daily potassium, phosphate and magnesium values, the time the results were received and documented at the bedside laboratory flow sheet by the ICU nurses. The time interval from identifying low levels potassium, phosphate and magnesium to the time replacement was initiated was noted. Information on replacement doses, post-replacement levels and adverse events during the infusion were collected.

The routine practice (control) in the ICU is for nurses to chart all results in the laboratory flow sheet. Any low potassium, phosphate and magnesium values are communicated to the physicians covering the ICU (residents, fellows or full-time intensivists). Physicians order replacement for all low levels unless there is a contraindication. Protocol-driven replacement (experimental) allows nurses to start replacements once a low level is identified using pre-set doses without communicating with the ICU physicians (see appendix A for the protocol). Endpoints were the time interval from identifying results to giving replacements and the number of replacements that were needed and not given.

After completing one month of data collection during the control period (routine care using PHD), the electrolyte replacement protocol that was developed by the investigators and approved by the pharmacy as well as ICU nurses was introduced for use in the ICU. The study was approved by the hospital research advisory council with waiver of consent. The introduction period was one month, during which in-services were given to all ICU staff on the proper use of the ICU protocol. No data collection was done during the introduction period. Once the protocol was used routinely by all nurses and without the knowledge of the ICU staff, the same data was collected over a one-month period.

SAS software was used to calculate the frequencies (percentages) of diagnoses. A descriptive analysis was applied for patient days in each group. The elapsed time between chemistry for each element and doses given for both arms were also plotted. The *P* values were then calculated for replacement doses among both arms for each element.

Results

Over the one-month of PHD, 43 patients were admitted to the ICU compared with 44 during the month of PDR. Patient characteristics are shown in Table 1. There was no significant difference in the number of episodes of hypokalemia, hypomagnesemia and hypophosphatemia episodes, nor the mean potassium, phosphate and magnesium levels.

There was a significant reduction in the mean time interval from identified low potassium, phosphate and magnesium levels to initiating replacement ($P<0.0001$) (Table 2 and Figure 1). There were 15 episodes of replacements needed and not given during the physician-driven month compared to 6 episodes during the protocol-driven month ($P<0.05$) (Figure 2). There was no significant difference in the number of post-replacement hypokalemia episodes and there were no side effects related to the infusions.

The mean replacement dose for potassium was 31.6 mmol during the physician-driven month compared with 24.5 mmol during the protocol month ($P<0.001$) compared with 15 and 17.8 mmol for phosphate, respectively ($P=0.0085$).

Discussion

To our knowledge, the efficacy of an electrolyte replacement protocol in the ICU has not been investigated. In this study, the use of a protocol for the correction of hypokalemia, hypomagnesemia, and hypophosphatemia resulted in more timely administration of the replacement dose, fewer missed episodes of low levels and was not associated with side effects. The findings of the study are consistent with previous studies assessing the use of protocols in the care of critically ill patients.[1]

Routine clinical care could be enhanced when interdisciplinary teams of health professionals use protocols in their patient care.[18] It has been shown that the use of protocols in caring for critically ill patients results in improvements in patient mortality and morbidity. For example, a protocol for the weaning of patients resulted in a significant reduction in mechanical ventilation days and a reduced frequency of ventilator-associated pneumonia (VAP).[19] Protocol-guided weaning of mechanical ventilation, as performed by nurses and respiratory therapists, led to extubation more rapidly than physician-directed weaning.[20] Daily interruption of sedative-drug infusions was found to decrease the duration of mechanical ventilation and the length of stay in the intensive care unit compared with interruption based on the physician order.[21] The incidence of delirium in critically ill patients may be as high as 82% and is associated with high mortality and morbidity.[22] Use of goal-directed sedation protocols in the ICU could reduce this incidence and improve patient outcomes, including long-term cognitive recovery. In addition, use of a protocol helped in decision making on end-of-life care.[23] On the other hand, the absence of protocols for the preparation of parenteral drugs was associated with drug administration errors in the intensive care unit.[24] The absence of protocols could also be responsible for poor compliance with published evidence-based guidelines for patient management.[25]

The electrolyte replacement protocol used in our study (Appendix A) was developed after consulting the literature, clinical pharmacists and ICU consultants in the unit. The replacement doses appear to be safe and effective.[26-29] However, there appears to be a need to adjust the potassium replacement dose upward in the protocol-driven strategy to match or even exceed the physician driven doses in order to decrease the occurrence of post-replacement hypokalemia.

Table 1. Patient characteristics.

	Physician-driven electrolyte replacement	Protocol-driven electrolyte replacement
Patients admitted	43	44
Patients excluded	0	11
Patient days	234	133
Sex:		
Male	20	20
Female	23	13
Mean age (y)	51.6 (16-84)	43.4 (14-80)
Diagnosis		
Medical patients	16	10
General surgery	20	16
Neurosurgery	7	7
Number of Episodes		
Hypokalemia	52	48
Hypophosphatemia	48	42
Hypomagnesemia	20	29

Table 2. Physician-driven electrolyte replacement vs. protocol-driven electrolyte replacement in ICU patients over one-month periods.

	Physician-driven electrolyte replacement	Protocol-driven electrolyte replacement	*P* value
Mean time (minutes) from identifying results to replacement			
K	161	19	<0.0001
PO_4	187	26	
Mg	189	19	
Number of replacements needed and not given			
K	9	2	<0.05
PO_4	6	4	
Mg	0	0	
Mean K dose given (mmol)			
K	31.6	24.5	<0.0001
PO_4	15.0	17.8	0.0085
Post-replacement hypokalemia (episodes)*	13	15	NS

K=potassium, Mg=magnesium, PO_4=potassium, NS=not statistically significant
*No patient had high post-replacement K, Mg, PO_4

Figure 1. Mean time from identifying electrolyte results to starting replacement in the physician-driven (PHD) vs. protocol-driven patients (PRD).

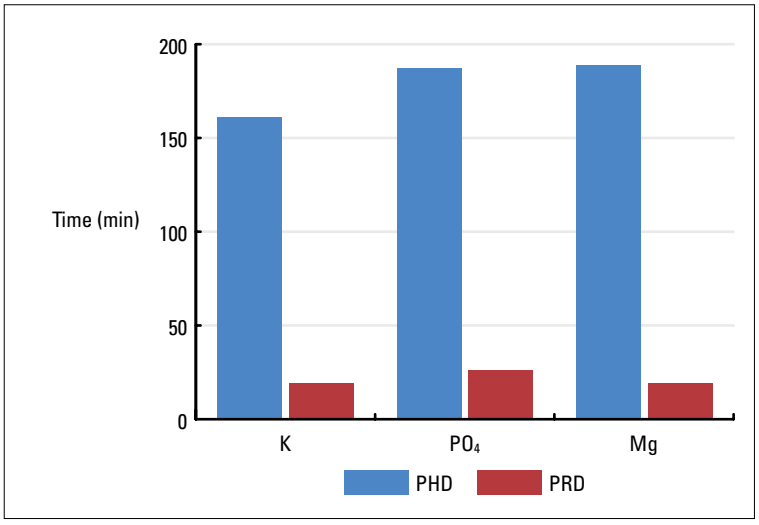
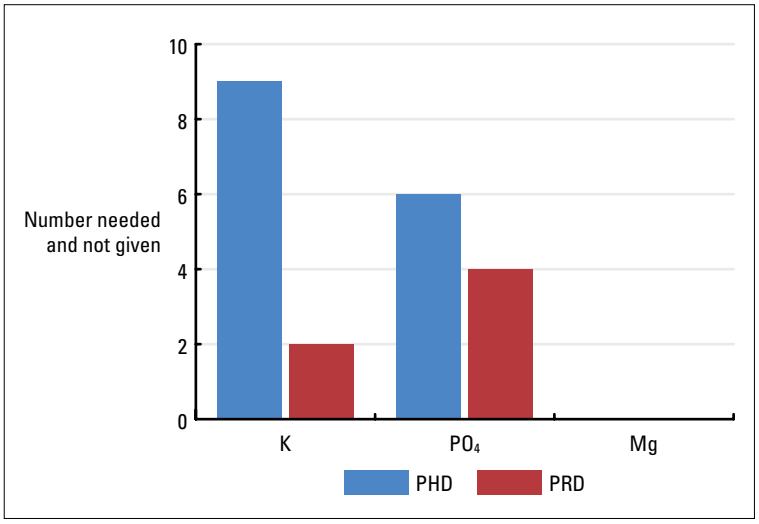


Figure 2. Number of replacements needed and not given in the physician-driven (PHD) vs. protocol-driven patients (PRD).



One of the advantages not shown by numbers in this study is the increased satisfaction of nurses because of the empowerment given to them by the protocol. The nurse's role in implementation of different treatment protocols, as well as satisfaction, was proved in a number of other studies.[30,31] The inclusion of a multidisciplinary team of clinicians, including nurses and respiratory therapists, is required to ensure protocol acceptance as well as success.[32,33] Moreover, the reduction in the number of calls received by physicians for electrolytes disturbances was welcomed by the housestaff.

On the other hand, the exposure of residents to electrolyte disturbances and correction decreased significantly after using the protocol, which may have affected their training. This disadvantage can be overcome by conducting in-services on the use and background of the electrolyte protocol for all residents rotating in the ICU, which will also help to overcome the problem that physicians tended to rely on their past experience and background in making decisions rather than looking at policies and protocols.[34]

The use of a protocol to replace low potassium, magnesium, and phosphate in the ICU setting is safe, easily applicable and can result in the delivery of more efficient care when compared to routine physician-driven replacement. However, there appears to be a need to adjust the potassium replacement dose upward in the protocol driven strategy to match the physician driven doses.

Standardization of care is important in a complex environment such as the intensive care units where excess information could exceed human decision making limits, thus increasing the likelihood of inadequate care.[35] It is worth mentioning that protocol implementation remains an important factor. For example, in the protocol-driven group, 6 episodes of low phosphate were not replaced. This emphasizes the need for regular in-service and staff education to ensure compliance and full implementation of the protocol.[36,37] Decision-support tools such as computerized protocols can have favorable effects on clinician and patient outcomes.[38,39] More research and wider distribution of such systems for commonly occurring problems in the ICU, like electrolyte imbalances, have the potential to improve patient care in the future.

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Appendix A

I.V. Potassium, Magnesium, and Phosphate Replacement Protocols For Adult Critically Ill Patients

Date & Time:_____

Assessment:
- Check serum Potassium, Magnesium, Phosphorus and Creatinine levels daily.
- Examine the ECG monitor for dysrhythmias.

Exclusion:
- Creatinine >115 micromol/L or urine output <30 mls/hr for 2 hours before the replacement.
- Dysrhythmias • Seizures • Weight <45 kg • Diabetic Ketoacidosis

Intervention:
- Call MD in the presence of any exclusion criteria
- Replacement must be done using an infusion pump under continuous ECG monitoring.

- **Potassium replacement:**

Serum K+ mmol/l	Peripheral I.V. Replacement	Central I.V. Replacement
3.3 – 3.5	20 mmol KCl in 250 mls NS over 2 hrs	20 mmol KCl in 100 mls NS over 1 hr
3.0 – 3.2	30 mmol KCl in 500 mls NS over 3 hrs	30 mmol KCl in 100 mls NS over 2 hrs
2.6 – 2.9	40 mmol KCl in 500 mls NS over 4 hrs	40 mmol KCl in 100 mls NS over 2 hrs
<2.5	Call MD	

- **Magnesium Replacement:**

Serum Magnesium	Replacement
0.5 – 0.8 mmol/l	5 grams (20 mmol) Magnesium Sulfate in 100 mls NS over 5 hrs
<0.5	Call MD

- **Phosphate Replacement:**

Serum Phosphorus	Replacement
0.71 – 0.9 mmol/l	12 mmol Sodium phosphate in 100 mls NS over 4 hrs
0.5 – 0.7	21 mmol Sodium phosphate in 100 mls NS over 4 hrs
<0.5	30 mmol Sodium phosphate in 100 mls NS over 4 hrs

- Recheck K+ level 4 hrs post replacement, Magnesium and Phosphorus levels 24 hrs post replacement.
- Document replacement in the medications record.

Valid until _____ Physician Signature: _____ Pager No.: _____